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Research on the Positioning in WSN Based on an Improved DV-HOP Algorithm

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Abstract

In order to reduce the positioning error of the sensor nodes, this paper first analyzes the reasons for the low accuracy of DV - HOP algorithm currently, and then proposes an improved DV - HOP algorithm. The algorithm can be divided into four stages, including data information overlapping stage, average skip distance calculation stage, optimum choice of anchor nodes and redundant node positioning. In the data information overlapping stage, the joint probability density is used for improvement; in the average skip distance calculation, the zero deviation estimation value is introduced; in the optimal selection of anchor nodes, optimal strategy is used; and the nodes are positioned in the redundant node positioning with the method of gradually increasing the skip distance. Simulation results show that the algorithm of this paper can effectively reduce the position error in calculation and improve the positioning accuracy.

Keywords: *DV - HOP; joint probability density; zero deviation estimation*

1. Introduction

It has long been a hot topic to find ways to position the nodes in a wireless sensor network (hereinafter referred to as WSN) more accurately, mainly because the effect of node positioning is directly related to the coverage effect of WSN. Considering the actual situation, under the influence of its volume and surrounding environment and other factors, there would be some errors in positioning, and the greater the errors are, the worse the coverage effect will be; conversely, the smaller the errors are, the better the coverage effect will be [1-3]. At present, the WSN node positioning is mainly divided into two positioning algorithms, with one based on distance (Rang-based) and the other irrelevant to distance (Rang-free). The former is to obtain the location of an unknown node by actually measuring the distance between adjacent nodes, and the distance measurement methods commonly used are TOA,TDOA, AOA and RSSI and so on [4]. The latter is to estimate the distance of unknown nodes according to adjacent nodes, currently mainly by the DV-HOP algorithm [5]. The algorithm uses average distance of each hop and hop count product in the positioning of unknown nodes. The advantages of the algorithm are simple and easy to achieve, and the shortcoming is that it tend to rely on network structure. However, the actual situation of WSN is that the network topology structure is complex, and there are great errors in the substitution itself with average hop count and hop count product, which will directly cause problems in the positioning accuracy of algorithms. Scholars at home and abroad studied and improved the DV-HOP algorithm. In literature [6], a duplex communication radius algorithm was used, to reduce the difference in positioning errors due to different network topology differences. The literature [7, 9] proposed introducing the genetic algorithm and artificial bee colony algorithm into DV-HOP algorithm to correct the errors generated, which has achieved certain results. Literature [8] proposed the improved DVHop algorithm for node density

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zoning, to effectively improve the node positioning accuracy.

The paper first analyzes the positioning errors in DV-HOP algorithm and proposes an improved DV-HOP algorithm, which divides the DV-HOP algorithm into four stages including data broadcast stage, distance calculation stage, positioning calculation stage and redundant node positioning for implementation. The simulation experiment shows that the algorithm presented in this paper effectively reduces the error rate in node positioning and improves the coverage effect of nodes, which is worth publicizing to some extent.

2. Introduction of Basic Knowledge

2.1 A Brief Introduction to the DV-HOP Algorithm

(1) Store all the unknown nodes and obtain the average hop count value from the anchor node.

(2) Calculate the average value of the hop distance of each anchor node and send it to the network.

$$H_{ij} = \frac{\sum_{j \neq i} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j \neq i} c_{ij}} \tag{1}$$

In the formula, (x_i, y_i) and (x_j, y_j) represent the coordinates of the anchor node i and the unknown node j , c_{ij} represents the hop counts i, j between the two nodes.

(3) According to the principle of three points determining a plane, an unknown node requires at least n (n>3) anchor node hop distance values to get the coordinates of its position.

$$\begin{cases} (x_1 - x)^2 + (y_1 - y)^2 = l_1^2 \\ \quad\quad \cdots\cdots \\ (x_n - x)^2 + (y_n - y)^2 = l_n^2 \end{cases} \tag{2}$$

2.2. The Disadvantages of DV-HOP Algorithm

(1) The errors of corrected value

In wireless sensing, for all the unknown nodes, the product of hop counts and corrected value is used to represent the distance, which will lead to great errors between the distance estimated and the actual distance. Use the DV-HOP algorithm to calculate the distance.

(2) The estimation of unknown node distance is not accurate

In wireless sensor networks, the position of an unknown node is substituted with the product between the corrected value and the anchor node. Apparently, this way ignores that there are great errors in complicated cases of node positioning. In the above figure, the straight-line distance between N and C is 40, and the error rate is (50-40)/50=20%. Due to such an error, the positioning error calculated will be much greater. Therefore, using this method of estimation, it is impossible to reduce errors as far as possible.

(3) Maximum estimation

At present, the estimation method is widely used in DV-HOP algorithms to measure the positions of nodes, mainly because these algorithms are simple and easy to implement, but as an unknown node has to be positioned with three or more anchor nodes, there will be errors between an unknown node and the anchor node. It is easy to lead to cumulative errors in a certain range.

3. The Improved DV-HOP Algorithm

Based on the study of the positioning problems mentioned above, there are many factors found in this paper that will cause errors in node positioning. In this paper, an improved DV-HOP algorithm is presented, and the algorithm is divided into four stages, including data information overlapping stage, average hop distance calculation stage, optimal selection of anchor nodes and redundant node positioning.

3.1 The Data Information Overlapping Stage

In WSN, there is a certain unknown node receiving the information posted by the several surrounding anchor nodes, so that information overlapping will occur. The so-called information overlapping is shown in Figure 2. The unknown node N receives the information sent by several anchor nodes, and because there is a public area among the data broadcast sent by the anchor nodes (The dash area in Figure 1), and each anchor node transfers its information to the same node, information will be discovered in an overlapping way. This will lead to the increase of network communication cost and extra consumption in node positioning. Improvements are as follows:

(1) Each anchor node in the WSN identifies that adjacent unknown nodes can successfully receive data from the node, and store to form sets in the format of $\{x_i \mid y_1, y_2, \cdots y_k\}$, in which x_i represents an anchor node and $y_1, y_2, \cdots y_k$ can receive the number of the adjacent nodes with unknown information.

(2) Each anchor node sends sets to surrounding adjacent unknown nodes, and if the position nodes that can receive data information do not need to forward information, build a table in the format of $\{y_i, \{y_1, y_2, \cdots y_k\}\}$, representing y_i is sent from the anchor node i. After sharing information, the anchor nodes in the network will know their adjacent nodes, thus reducing the unnecessary loss of energy to a certain extent.

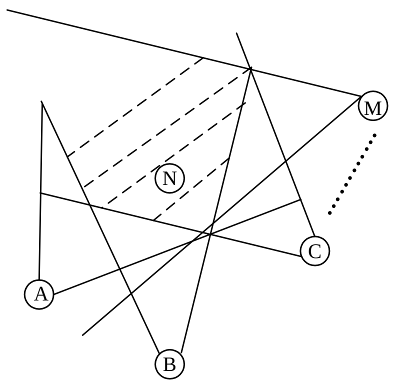

Figure 1. Information Overlapping

In the process of grouping above, the set of time limit for grouping has not been taken into consideration, to make most of the unknown nodes receive information from at least 3 anchor nodes following formula (2). In literature [10], it is presented when there are N anchor nodes distributed randomly in the area of $R \times R$, and if there are m anchor nodes in the range of $\pi(AR)^2$, A will be

$$A = \frac{1}{r}\sqrt{\frac{R \times R \times m}{N \times \pi}} \quad (3)$$

In the formula, A represents the maximum value that the minimum hop count can obtain, r represents the coverage radius of anchor nodes, m means the number of anchor nodes needed by unknown nodes for positioning, and N is the sum of all the anchor nodes. However, the limit hop count of value A in formula (1) is too small. Based on this, it is presented to use the joint probability density for improvement, assume that the random variable X represents the number of anchor nodes, $X \in [0, N]$, and use random variable Y to represent the area of the region, $Y \in [0, L \times L]$, so the formula is shown as (4)

$$\begin{aligned} f(X) &= 1/N \quad X \in [0, N] \\ f(Y) &= 1/L \times L \quad Y \in [0, L \times L] \end{aligned} \tag{4}$$

As there is no direct relationship between the number of anchor nodes and the area of the region, the joint probability density function $f(X, Y)$ of $f(X, Y)$ is obtained by using formula (4):

In the real environment of WSN, to set the number of anchor nodes contained in the A hop range of more than 90% of the nodes greater than m , set $P(x \geq m, y \leq \pi (AR)^2) \geq 0.9$ and transform it as follows:

$$A \geq \frac{L}{r}\sqrt{\frac{0.9N}{(N-m)\pi}} \tag{5}$$

Formula (5) can simulate the scenarios of different connectivity, and by modifying r to represent the value of the coverage radius of anchor nodes, the optimal hop count can be obtained.

3.2. The Calculation of the Average Hop Distance

The use of the hop distance in Formula (1) is just to make replacement with the average value, which will cause errors in the results. The paper presents the calculation by replacing the average value with zero deflection estimation, which enables a minimum value to be obtained in the overall error, and minimizes the error value. First, Formula (1) is used to calculate the average value H_{ij} of all the other anchor nodes, and then according to Formula (6), calculate the zero deflection estimated value of the entire network.

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} = H_{ij} + \varepsilon_{ij} \tag{6}$$

In formula (6), d_{ij} represents the real values of the anchor nodes i and unknown nodes j , ε_{ij} is the deviation generated by the hop distance value.

$$t_1 = \sum_{i \neq j} \varepsilon_{ij}^2 \tag{7}$$

According to the principle of the least square method, t_1 represents the sum of all errors. On the basis of the zero deflection estimation formula, let t_1 take the minimum value, and solve the H_{ij} partial derivative of t_1 , and let it be 0, to get the formula (8)

$$H_i = \frac{\sum_{i \neq j} d_{ij} H_{ij}}{\sum_{i \neq j} H_{ij}^2} \tag{8}$$

The average value of the entire network hop distance is replaced by the average hop distance of zero deflection estimation. This will enable the anchor nodes nearest to the unknown nodes to obtain the shortest hop distance value in the entire network, further reducing network expense.

3.3. The Optimal Selection of Anchor Nodes

In the DV-HOP algorithm, if the number of anchor nodes is smaller than that of the unknown nodes, the precision of positioning calculation error is relatively smaller. However, if the number of anchor nodes is more than that of unknown nodes, the optimal selection strategy described in this section is used to make selections, so as to guarantee the reduction of errors. It can be seen from the description of sections 2.1 and 2.2 that previously the farther anchor nodes are directly ignored, and in the positioning process, zero deflection estimation is used to get related information of anchor nodes, so in this section it is mainly to remove off the operation of similar anchor nodes.

First, calculate the distance between the two anchor nodes. If the distance is less than 0.5R (R as the coverage radius of the anchor nodes), anchor nodes are compared with other anchors, and so forth, until the condition is satisfied.

Second, calculate the 3 times ratio of the distances between an unknown node to the two anchor nodes and between anchor nodes. If greater than 10, it indicates that the information of the two anchor nodes are the same, one of them can be removed, so that the optimal selection of anchor nodes can be achieved.

The unknown node is set as N , and the anchor node as AB , and the distance between them is shown in Figure 2. Meet the formula (9).

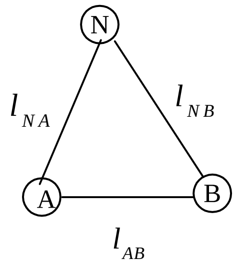

Figure 2. Anchor Node Positioning

$$\begin{cases} l_{AB} < 0.5R \\ \dfrac{l_{NB} + l_{NA}}{3l_{AB}} > 10 \end{cases} \tag{9}$$

3.4. The Positioning of Redundant Nodes

To improve the coverage rate of the node positioned, when the positioning operation is done, the redundant nodes failed in positioning send information to its adjacent nodes according to the number of messages of the missing anchor nodes, and when the nodes that have been successfully positioned receive the information, they will play the role of anchor nodes to send their own coordinate information to the redundant nodes. In sending information, they will use the one hop distance formula to make calculation. When the redundant nodes not positioned have visited all the adjacent nodes, those not responded will use two hops distance formula to send information to the nodes until the positioning is finished.

4. Simulation Experiments

In order to better verify the performance of the algorithm of this paper, 100 times of experiments are performed. Under the environment of Windows XP, with CPU core i3 and memory 4GDDR and Matlab2010 as the simulation software platform, a 100m*100m monitoring area is set, and the node communication radius is R=20m. In the network, 100 nodes are deployed, and the proportion of anchor nodes is in the range of 5%-30%, which is set according to the different situations in the experiment sites.

4.1. The Manual Deployment of Anchor Nodes

In the sensor network, the anchor nodes are deployed manually in accordance with different proportions, and the algorithm of this paper is compared with the DV-HOP algorithm and the algorithm in literature [6], as shown in Figure 3.

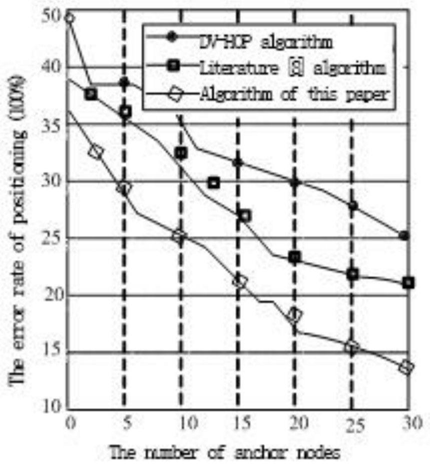

Figure 3. The Relation between the Number of Anchor Nodes and Positioning Error

From Figure 3, it can be seen that when anchor nodes take up a proportion of 5%, 10%, 15%, 20%, 25% and 30%, respectively, the error of this algorithm is reduced by 8%, 12.13%, 12.27%, 12.19%, 14.25% and 11.12% to the largest extent compared to those of the other two algorithms. When the anchor nodes take up 20% of nodes, the best improvement effect of the positioning algorithm can be achieved.

4.2. The Influence of Topology Structure

Different topology structures have different influences on the positioning error. In this paper, the network typology structure described in literature [11] is used as the testing standard, in which the C-type reticle topology is No.1 topology, and the realistic simulation topology structure is No. 2 topology. The results of the algorithm of this paper, DV-HOP algorithm and the algorithm in literature [8] compared in these three topology structures are as follows:

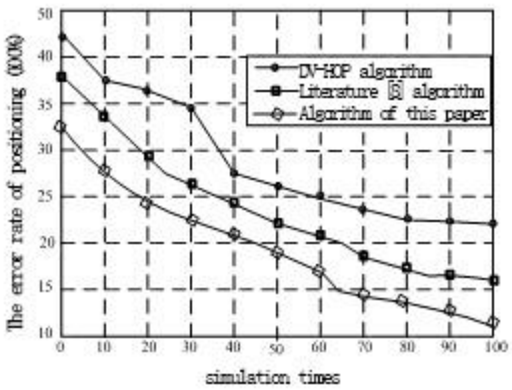

Figure 4. Error Rate of Three Algorithms under the Structure of Topology 1

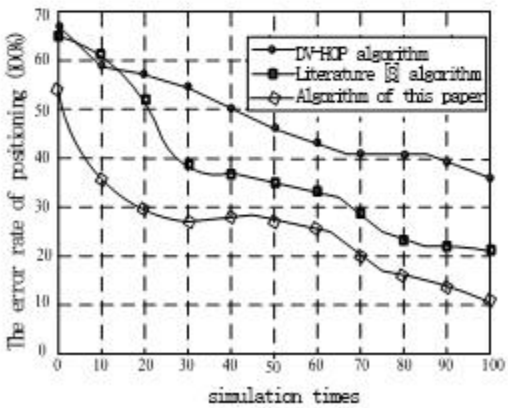

Figure 5. Error Rate of Three Algorithms under the Structure of Topology 2

It is found in Figure 4-5 that the algorithm of this paper is clearly superior. The distribution of nodes in the topology structure in Figure 5 is rather unbalanced, but the algorithm of this paper makes the average hop distance of each unknown node more consistent with the actual situation and improves the success rate of node positioning. The topology structure in Figure 6 is mainly for verifying the positioning errors in case that the nodes get close to the boundary. This algorithm can effectively solve the problem.

5. Conclusion

This paper focuses on solving the problems of the DV-Hop algorithm and presents an improved DV-HOP algorithm, which is divided into four stages, namely, the information overlapping stage, average hop distance calculation stage, the optimal selection of anchor nodes and redundant node positioning, and the improvement for each stage is described. The simulation results show that the algorithm of this paper improves positioning accuracy and is more practical.

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